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Design and Construction of a Glass Casting Furnace

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ROCHESTER INSTITUTE OF TECHNOLOGY
SCHOOL FOR AMERICAN CRAFTSMEN

DESIGN AND CONSTRUCTION OF A GLASS
CASTING FURNACE

A THESIS SUBMITTED IN PARTIAL
FULFILLMENT FOR

A MASTERS OF FINE ARTS DEGREE

BY

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ROCHESTER, NEW YORK

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INTRODUCTION

The contemporary movement of glass has formerly been geared to blown 'container' forms. My background and knowledge of the material has previously followed this line of endeavor. Recently I decided to expand the conventional framework of contemporary glass by attempting to cast large sculptural and architectural forms. Realizing that a process involving casting on this scale would involve more glass than could be handled in a conventional manner, i.e. ladled or shoveled, I decided to construct a furnace that would realize these goals.

In attempting this project, my goals were to design a furnace with casting capabilities that could be easily and economically built and used in a school studio situation. The furnace would be designed to accommodate a sufficient quantity of glass to be poured into molds of varying sizes. My main concerns lie in the safety, durability, and efficiency of the system. This thesis will show the experimental direction I have taken.

I wish to express my gratitude to Thomas Kekic, head of the glass department at the School for American Craftsmen at the Rochester Institute of Technology for his technical

assistance.

I. FURNACE FRAMEWORK

In considering the superstructure of the furnace, my main concern lie in the durability and strength required to support a tilting furnace. The furnace would weigh six hundred pounds empty, and seven hundred and fifty pounds with a full charge of glass, depending upon the chemical composition of the glass used. The basic frame for the system was acquired from a glass factory in Cincinnati, Ohio, through the diplomatic efforts of Thomas Kekic. The managers of the company expressed great interest in my experimental ideas and were happy to donate the frame which originally had been part of an acid tumbling/polishing operation, making it ideal for adaptation to my purposes.

To elevate the frame to a suitable height to facilitate pouring, I built a supporting framework of two inch tubular steel. (refer to blueprints one and two) The bearings and turning mechanism were constructed of a combination of materials of superior strength. Having elevated the tilting frame, I attached ten feet of stainless steel rollers to the unit upon which the mold would roll to and from the pouring spout. I had hoped to build my annealing oven at the opposing end of the rollers so that the mold with the cast glass piece could be introduced directly into it after each pour, however, the lack of sufficient electrical power at the pouring site forced me to adapt a different solution.

Utilizing a sixty gallon capacity barrel for the melting chamber, the first step was to remove the one quarter inch vulcanized rubber layer which coated the inside surface. Once this was completed by burning away the layer, I cut a spout opening in one side, approximately six inches in diameter. I then began casting the refractory material.

A glass melting furnace traditionally relies on several different kinds of glass contact and insulating materials to keep heat and glass inside the chamber. The process of casting the refractory inside the barrel was done in several stages utilizing various refractories developed for specific purposes.

A core form had to be constructed to occupy the interior spaces around which the first layer of refractory insulation was cast. With the form in place, the outside insulating layer of A. P. Green Block Castable 1900°F was cast two inches thick. (refer to blueprint three) This layer was cured for twenty-four hours at room temperature. The first core form was removed, and a second, proportionally smaller core was placed inside the cast shell allowing a two inch layer of La France Hydrocon 2700°F Castable refractory to be cast into place. This layer also cured for twenty-four hours at room temperature.

With the second form removed, the glass holding tank was constructed of A. P. Green Crystolite Splits which were mortared in place. Next, a spout was constructed of a two inch thickness of Hydrocon. This procedure proved unsatisfactory as the

Hydrocon was not strong enough to withstand the corrosive attack of the glass.

The crown or roof for the furnace was the last step in completing the melting part of the system. The first casting attempt was a failure because the crown could not be removed once it was cast. Since the furnace was designed to be charged from the top, I redesigned the crown so that it could be removed.

On the second attempt, the inside of the barrel was liberally greased so as to provide a release for the cast piece and a one quarter inch copper shim was left. This attempt proved successful as the form was easily removed after curing. La France Hydrocon 2700°F was used for the inner surface; two inches of A. P. Green Fiberfrax blanket insulation was used as a backing on the outer surface. Upon casting the crown, an eight inch diameter opening in the center of the crown was left to later accommodate the burner block. With the completed refractory crown in place, the barrel and cover were secured by means of a steel cover plate and a fastening band.

I selected a one and one half high pressure venturi burner with a cast refractory burner tip. Since this type of burner requires the tip to be buried in the crown of the furnace, a burner block was fabricated from four 3000°F insulation bricks mortared together. A six inch diameter hole was carved in the center of the block into which a Gibberson burner tip was fitted

and attached to the before mentioned one and one half inch Venturi type burner. At this point the furnace was completed.

II. MOLDS

Molding and casting are processes of reproducing an object in form and texture, identical in appearance with the original from which the copy or reproduction is made. To obtain such casts there are two main processes to be undertaken. The first is that of producing the mold or negative. The second is the making of the cast or positive from the mold. In other words, a mold is an impression of an object while a cast is an impression of the mold.

J. S. Vanick classified the general requirements of mold materials and graded them as to importance. His listing is as follows:

(a)	Machinability.	200 points
(b)	Fineness of Surface Finish.	100 points
(c)	Density or Homogeneity. . .	100 points
(d)	High Graphite Particle Distribution.	100 points
(e)	Resistance to Heat Checking.	100 points
(f)	Low Thermal Expansion. . .	100 points
(g)	High Thermal Conductivity.	100 points
(h)	Resistance to Surface Deterioration.	100 points
(i)	Resistance to Growth and Scaling.	50 points
(j)	Resistance to Wear, Corrosion and Staining. . .	50 points
TOTAL		<u>1000 points</u> 1

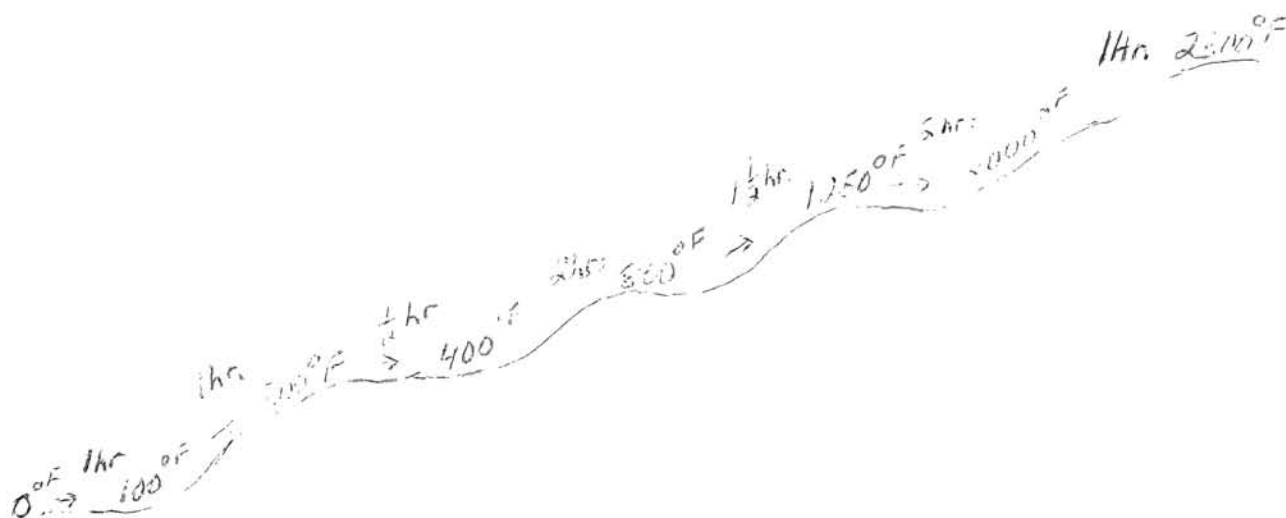
¹Fay V. Tooley, ed., Handbook of Glass Manufacture (New York: Ogden Publishing Co., 1961), p.449

This chart provided a reasonably practical tool to evaluate the desirable characteristics and relative advantages of the mold materials under consideration. There is one main disadvantage to this listing, this being that the cost of the material is not taken into consideration. Several mold materials such as foundry sand, steel, aluminum and cast iron could be utilized with this pouring technique, however,* their cost factors and the need for them to be cast in a foundry make them impractical in my present situation. Graphite proved to be the ideal material for the molds as it can be easily worked with relatively unsophisticated equipment. In forming the mold I used in my experiments, the design was carved and drilled into the graphite slab. Although graphite is an excellent material for withstanding the extreme thermal shock caused by contact with molten glass, it does have a disadvantage in that it deteriorates with prolonged and repeated exposure to hot glass and tends to discolor the contact surface of the glass. No problems were encountered in separating the casting from the mold as there were no undercuts on the mold. The duration of time the casting spent in the mold became a critical factor due to the different coefficients of expansion and the tendency of the mold to quickly draw the heat from the cast glass. If the casting was not removed from the mold within ten to fifteen minutes after casting, it became difficult

to dislodge.

III. MELTING AND POURING

The melting tank was brought up to temperature very slowly the first time due to the thickness of the castable materials and their tendency to crack if heated too fast. The refractories are hygroscopic necessitating a heat curing process upon firing to prevent cracking and spalling. Figure A describes the initial firing/curing rate.



At 2100°F, I began charging the furnace. In three instances twenty-five pound charges were used with an hour in between charges before the tank was full. The glass was allowed to melt before the first pouring to rid itself of any bubbles trapped during the initial melting. The results of the first pour were disappointing as several factors were misjudged. First, the temperature of the glass at the time of the pouring was too low

causing the glass to flow improperly. Secondly, the tank did not empty completely and there was not enough molten glass to fill the mold. These problems were easily rectified by increasing the pressure of the gas entering the burner from fifteen p.s.i. to thirty-five p.s.i., which jumped the temperature considerably and doubled the quantity of glass melted. There were no apparent problems with thermal shock to the furnace walls as they had been heat cured properly. Figure B will describe the second revised heating cycle with the melting cycle reduced from eleven and one half to between six and nine hours. Consecutive pours proved this theory possible by recharging the furnace immediately after pouring followed by a two and one half hour melt.

IV. GLASS

The type of glass used in the casting furnace is as important as the structure of the furnace itself. For this type of machine working, a glass with a long working range is necessary to insure the maintenance of a proper temperature for the glass to fill the mold and conform to the most specific detailing. I had been using commercial soda-lime glass in my previous work, but found this type of glass to be inefficient for casting purposes. The lime content was too high, causing the glass to 'set' too fast. As a result, I experimented with lead crystal cullet. This glass proved to have a lower melting temperature, requiring less fuel; a greater density, enabling it to hold heat longer; superb optical qualities which I felt would enhance the particular form I was casting; and by melting lead cullet as opposed to lead batch, I could further reduce the melting temperature and eliminate the risk of lead poisoning.

V. ANNEALING

The purpose of annealing glass is to bring the object to a temperature which will relieve the internal strains caused by shaping the glass without distorting the desired shape of the object. Cooling must follow in a manner which will not introduce new strains or tensions. In considering the annealing rate for the form I was casting, the overall thickness of the piece, the variations of thickness in the piece, and the overall

size of the piece were the most important factors. The molded forms varied in thickness from one and one half inches to one inch. Theoretically, each different thickness would require an annealing rate of its own, however, the greatest thickness must be used to calculate the proper annealing temperature at which the internal stress is substantially relieved. This temperature is found by the use of Dr. H. H. Holsher's formula:

$$n = \frac{mgl}{3r^2 (dl/dt)}$$

where:

n = viscosity in poises,
 m = load in grams,
 g = acceleration due to gravity =
 980 cm. per. sec. per sec.,
 l = heated or effective length of
 fiber in centimeters,
 r = fiber radius in centimeters, and
 $\frac{dl}{dt}$ = elongation rate in centimeters per second. 2

My forms were placed in the annealing oven at 950°F, and allowed to soak for three hours. The temperature was gradually reduced over a period of twelve hours from 950°F, to room temperature.

During my first annealing trial, I encountered trouble due to the extreme softness of the lead oxide glass that I was using. Lead glass anneals at a considerable lower temperature than soda-lime glass with which I am familiar. Annealing at too high a

²Fay V. Tooley, ed., Handbook of Glass Manufacture (New York: Ogden Publishing Co., 1961), p. 451

temperature results in characteristic 'slumping' or deforming of the piece. The problem was easily rectified by lowering the soaking temperature, in this case, a drop of 100°F to 850°F.

In conclusion, I feel that my casting experiments with this furnace at this point have been successful. However, some of the details yet to be perfected are; (a) the use of a denser refractory for the spout, or a commercially manufactured spout; (b) the placement of the annealing oven, as castings tended to cool unevenly during transition from furnace to oven. I would recommend the annealing oven be placed as close as possible to the furnace, as in my original plans.

I feel this casting technique is a valid direction of research for both the studio glass worker and the individual student, as most of the skill is involved in sculpting the mold which is worked cold, and can be manipulated over a greater period of time. I found the only limitation set upon this process to be the size of the annealing oven which can be constructed to sufficiently embody and anneal the piece.

GLOSSARY

Block Castable	An insulation type refractory utilizing water as a catalyst.
Burner Block	The fixture which holds and supports the burner above the furnace proper.
Charging	Feeding the furnace a quantity of substance, i.e. chemical batch or cullet
Curing	Preservation as by aging; to subject to chemical action or heat in order to render infusible or chemically inert.
Giberson Tip	A specific type of burner tip designed and sold by Dudley Geberson, Vermont.
Graphite	A soft, black chemically inert variety of carbon having mettalic luster and a slippery texture. It is used as a lubricant and in making electrodes, crucibles, etc.
Hydrocon	A specific brand of castable refractories.
Hydrascopic	Any of a class of compounds associated with water.
Shim	In machinery, stoneworking and railroading, a piece of metal or other material used to fill a space, as where joints are worn loose, or between something and its support.
Slump	A collapse or deformity usually caused by bringing a substance close to its inherent melting point.
Soak	To allow a substance to absorb, as to soak water, heat, etc.
Split	A term referring to a standard brick size measuring one and one quarter by four by nine inches.
Spalling	To break up or split at the edges as a stone under pressure.
Thermal Shock	A sudden drop or rise in temperature.

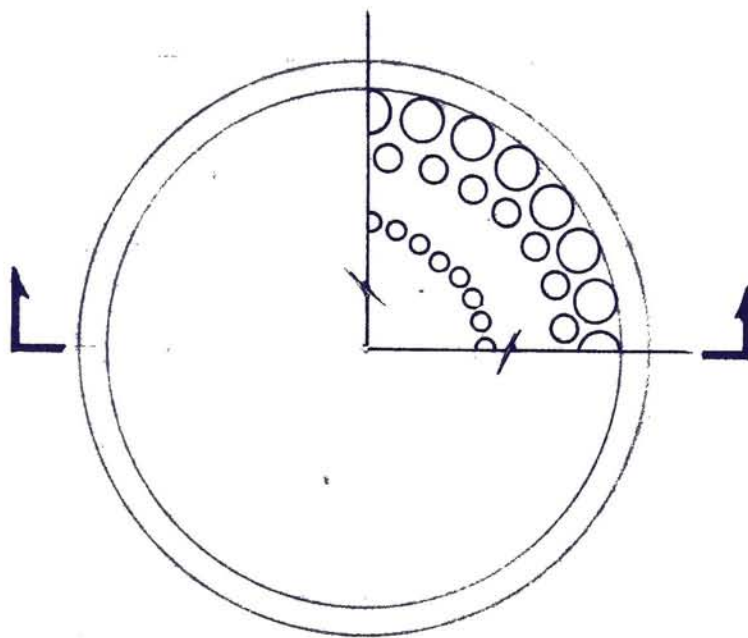
Venturi

A short tube with a constricted part, connected with a pipeline to permit computation of the rate of flow by the pressure difference between the narrow segment and the main diameter of the pipe.

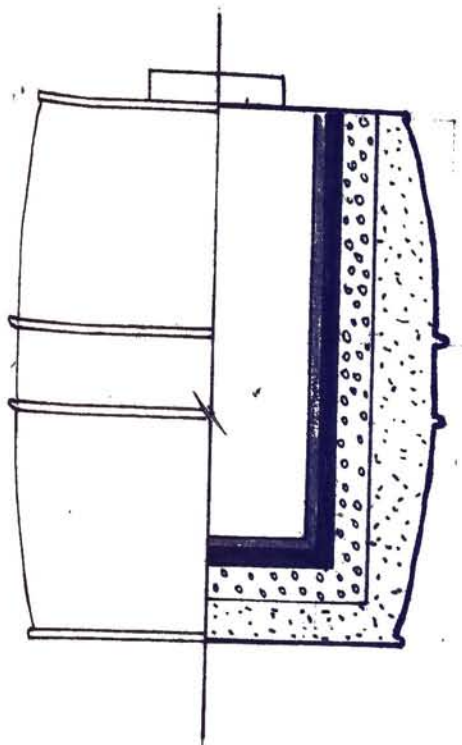
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MOLD DETAIL
ONE AND ONE HALF INCH EQUALS ONE FOOT

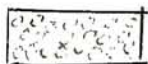


BARREL DETAIL

ONE INCH EQUALS ONE FOOT



A.P.Green Block Castable 1900° f



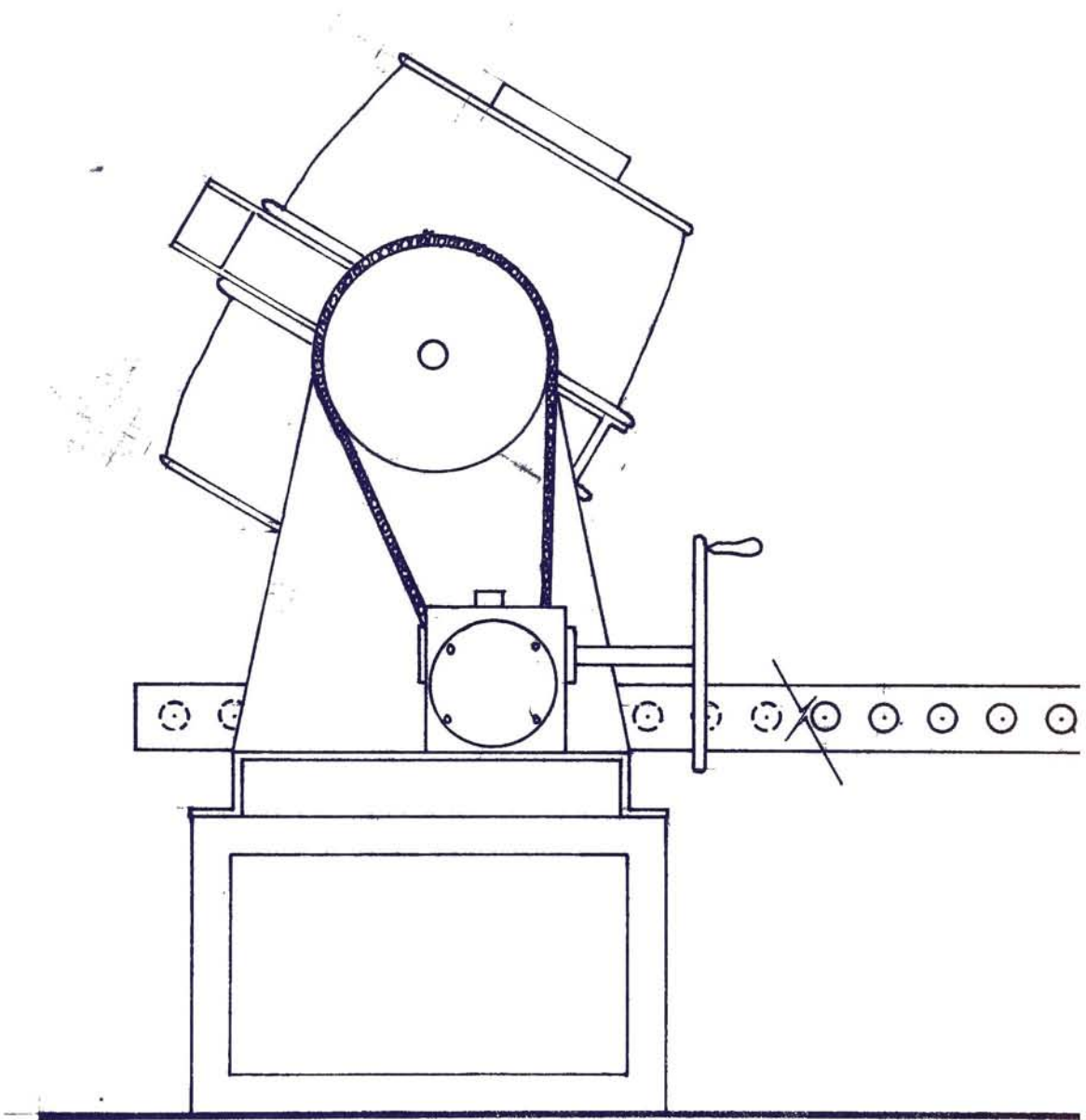
LaFrance Hydrocon Castable 2700° f.

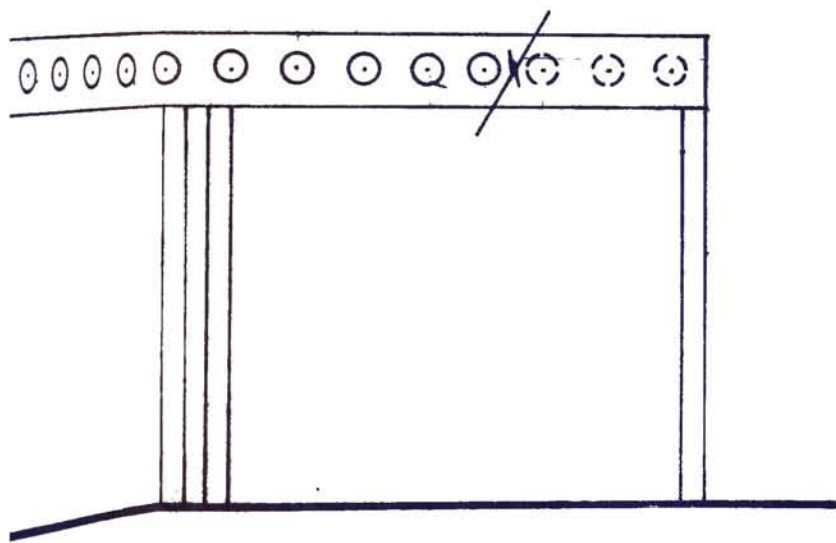


A.P.Green Crystalite Splits 99.

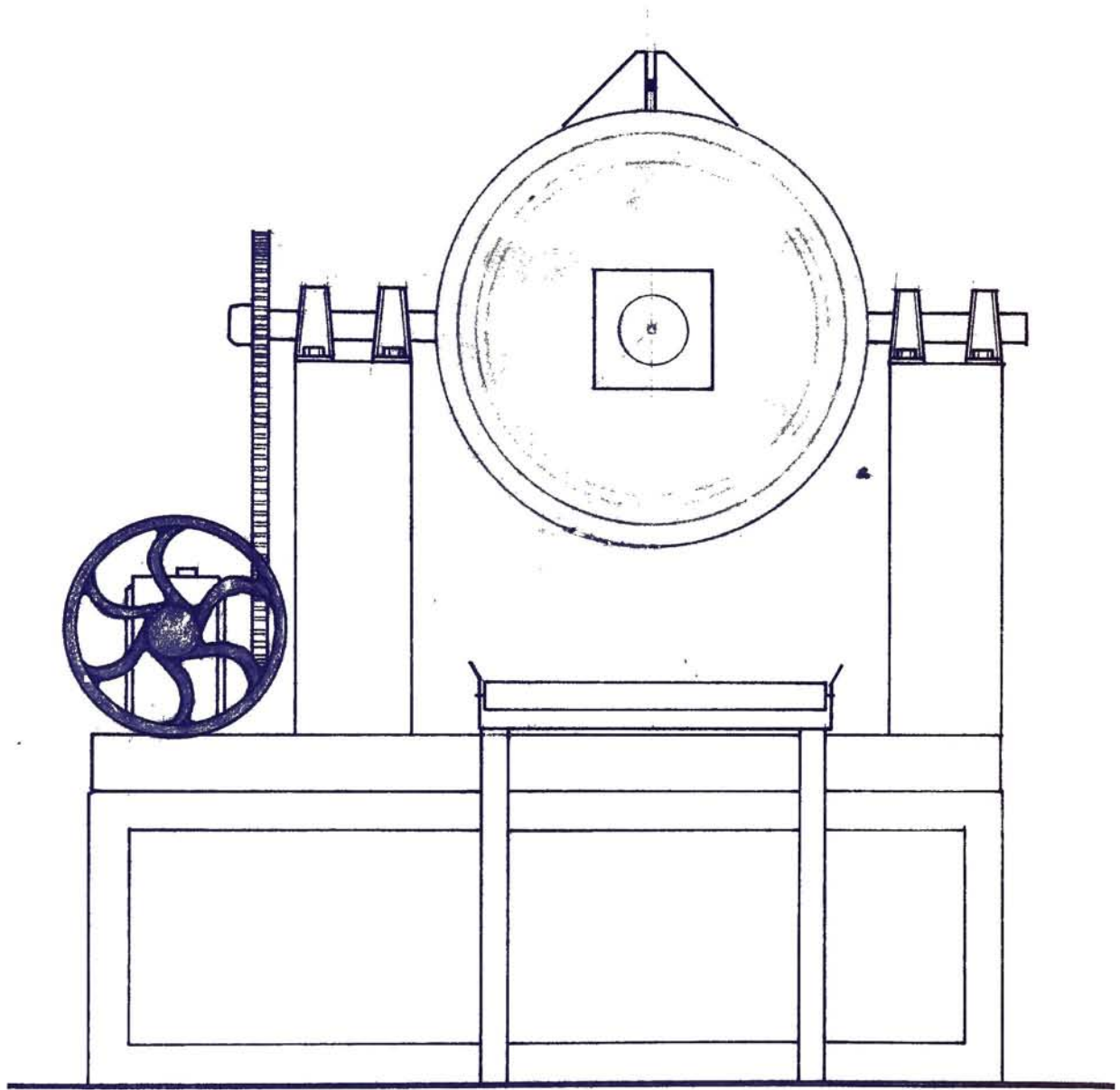
LINOLSI TILTABLE CASTING FURNACE

ARTIST: L. LINOLSI MAY 19, 1975





LIVOLSI TILTABLE CASTING FURNACE
ARTIST: L. LIVOLSI
MAY 19, 1975



FRONT ELEVATION



SCALE: ONE INCH EQUALS ONE FOOT

LIVOLSI TILTABLE CASTING FURNACE

ARTIST: L. LIVOLSI MAY 19, 1975





